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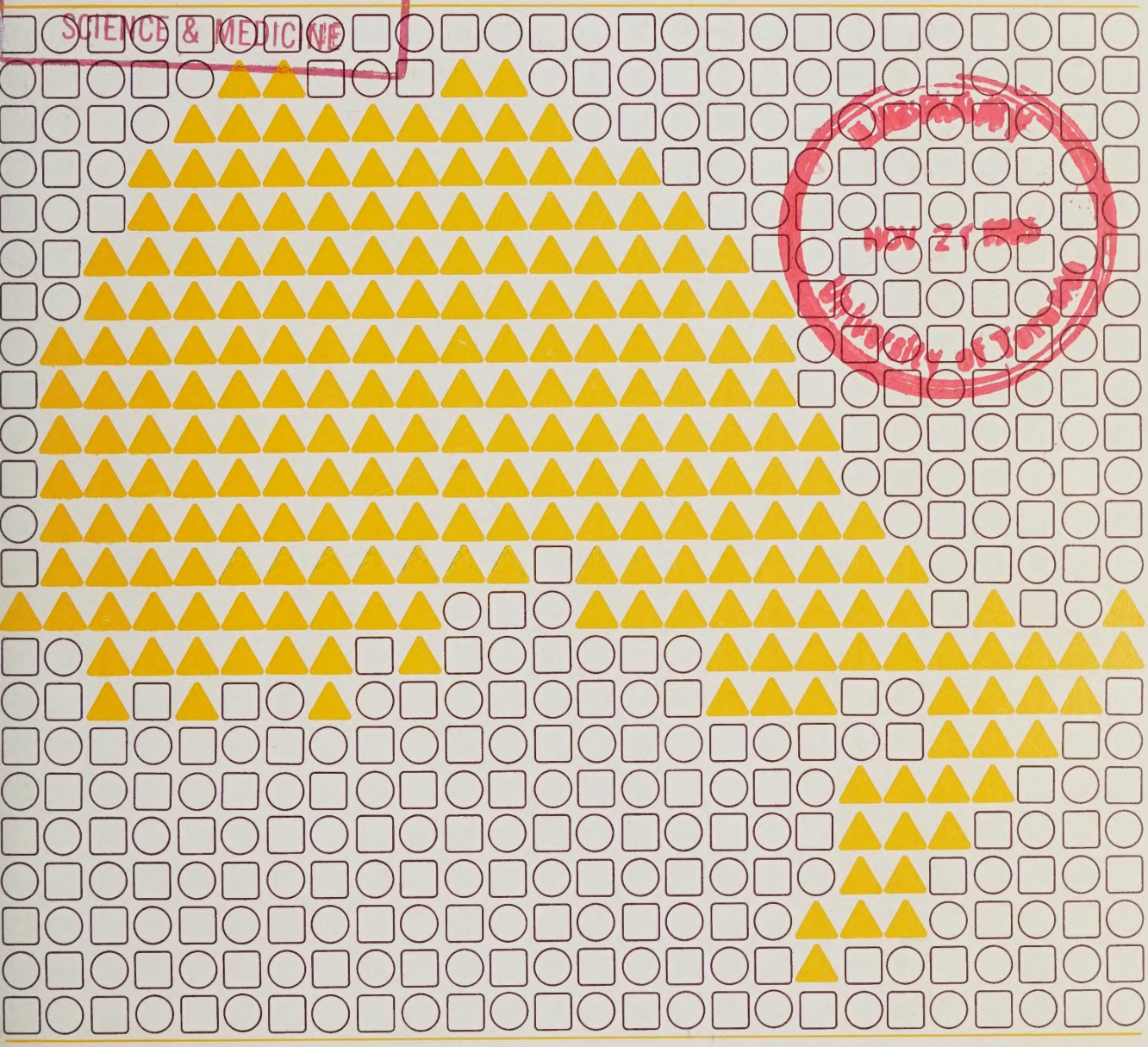
# Occupational Health in Ontario

Volume 6, Number 4, Fall 1985

***Blood Lead Analyses: Methods, Proficiency and Trends in Results***

***Vanadium***

***Exposure to Ethylene Oxide in Hospitals in Ontario***



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# Occupational Health in Ontario

Volume 6, Number 4, Fall 1985

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2. Department of Health and Social Security, Notes on the diagnoses of occupational diseases. Rev ed. London: HMSO., 1972.
3. Gamble JF, and Battigelli MC. Epidemiology. In: Clayton GD and Clayton FE. eds. Patty's industrial hygiene and toxicology. New York: McGraw Hill, 1978: Vol 1; 113-116.

I. R. Walkinshaw,
B.Sc.,L.R.I.C.

# Blood Lead Analyses: Methods, Proficiency and Trends in Results

**Summary**

*The three principal techniques for blood lead analysis, including the one chosen by the Occupational Health Laboratory, and programs for testing proficiency of lead-in-blood analyses are described. The analyses performed by the Occupational Health Laboratory over the last six years are reviewed and indicate that, on average, the levels of lead-in-blood in workers are decreasing.*

*I.R. Walkinshaw, B.Sc., L.R.I.C.*
*Occupational Health Laboratory Service,*
*Ontario Ministry of Labour,*
*101 Resources Road,*
*Weston, Ontario*
*M9P 3T1*

In 1978 the Ontario government took its most encompassing step towards protecting worker health in Ontario by enacting the *Occupational Health and Safety Act*. This amalgamated a hitherto assorted collection of health and safety acts into a single, well defined statute for the benefit of employers and workers in the province.

A tangible result of the new emphasis on occupational health was a major increase in staffing and the acquisition of a variety of state-of-the-art analytical equipment for the existing Occupational Health Laboratory (OHL). The culmination of this expanded and improved program occurred in 1981 with the opening of the newly constructed and equipped OHL at 101 Resources Road, in Weston, Ontario. This facility has 25,000 square feet of modern laboratory space, a staff of 37 scientists, technicians and support staff and a broad range of the most up-to-date analytical equipment to be found anywhere in the world today.

One of the first major occupational contaminants for which analytical techniques were reviewed by the enlarged OHL was lead. The regulation for lead, which came into force in 1981, lays down very specific, enforceable guidelines for the control of lead in the workplace. It calls for a time-weighted average exposure concentration (TWAEC) of 0.15 mg of lead per cubic metre of air and, in the case of exposure to tetraethyl lead, 0.10 mg of lead per cubic metre of air. The regulation also calls for medical surveillance of potentially exposed workers and mandates 3.4 μmol lead per litre of blood (0.70 mgPb/L) as an alert level indicating excessive exposure. If this concentration is ever recorded a further test must be undertaken immediately and, if the result is confirmed, the worker must be removed from further lead exposure, although symptoms of lead intoxication are unlikely to be apparent at this level. If symptoms or signs of lead intoxication are present, the worker must be removed from lead exposure regardless of blood lead level. The only exception to this rule applies to women capable of bearing children. In these cases, in order to safeguard the developing fetus,

the alert level is set at 1.9 μmol of lead per litre of blood (0.4 mgPb/L).

The regulation also specifies the method to be used for the analysis of lead in blood. This method was chosen for the Code for the Determination of Lead in Blood by the OHL after much consideration and by a process of elimination of the analysis methods then available.

## Methods

Over the years lead in blood had been determined by a number of different analytical techniques:

- extraction/colorimetry
- anodic stripping voltammetry (ASV)
- atomic absorption spectrophotometry (AAS)

The first of these methods, extraction/colorimetry, is no longer in favour because of the complexity and slowness of analysis, interferences and its relatively poor detection level.

The second method, ASV, has proven to be popular in clinical laboratories since it is an electrochemical technique that can be used to measure a number of different analytes. This versatility has made it a very cost effective method. It is also accurate and has the capability of producing very good detection levels. Its major drawback for blood lead analysis is that it is a very slow and relatively complex technique, which would make it impossible for any laboratory with a large blood lead sample load to attain good sample turn-around-times. A remedy for this drawback is available in commercial chemical kits. A predetermined amount of chemicals necessary to digest the blood comes in a prepackaged form ready to add to a blood sample before analysis. These kits, however, are very expensive and their exact composition is a proprietary secret.

The third method, AAS, is currently the most popular for blood lead analysis. This method employs two major techniques, namely, the graphite furnace technique and the Delves cup technique. Both are accurate and have comparable detection levels. The Delves cup technique is, however, considerably faster and the cost of the apparatus is approximately $10,000 less than that required for a good graphite furnace. The Delves technique allows the OHL to analyse about 120 blood lead samples per day and record a detection level of 0.24 μmol of lead per litre of blood (0.050 mgPb/L). The test itself is similar to the well-known tantalum boat technique. In this case,

however, 10 μL of well-mixed blood is transferred to a small, round, nickel cup (i.e. Delves cup). The blood is then dried, introduced into an air-acetylene flame and the resultant signal measured on a chart recorder. The signal is measured at 217 nm.

## Proficiency

The ultimate aim of any analytical technique is to produce consistently accurate results. To this end the OHL participates in a comprehensive quality assurance (QA) program, which is divided into two parts, internal and external.

The *internal* QA program consists of checks on every sample run, by means of control samples and the maintenance of a control logbook to highlight undesirable trends. Also, a check is carried out bi-monthly using samples prepared by the internal QA section; these are analysed as blind samples.

The in-run controls mentioned above are not just repeats of calibration standards. They are real blood samples drawn from collected pools of worker-exposed-blood that have known blood lead concentration values and freeze-dried products purchased from reliable suppliers of clinical controls.

The bi-monthly QA check uses three blood samples that must be analysed within 10 days of receipt. The results, which are known only to the QA section, must fall within a specified range to be considered proficient. The proficiency range is the same as that specified by the Center for Disease Control, Atlanta, and is:

0–1.9 μmol Pb/dL : ± 0.29 μmol
> 1.9 μmol Pb/dL : ± 15%

This range corresponds to a 95 per cent confidence level.

The OHL also participates in three *external* QA programs sponsored by:

1. The Center for Disease Control, Atlanta
2. The Centre for Toxicology, Laval University
3. The West Allis Memorial Hospital, Wisconsin

The Atlanta validation is considered to be the most important of the three programs. The centre sends three blood samples per month, which the OHL analyses and reports back on within seven days. These samples are obtained from cows that have been fed gelatin capsules containing lead acetate. The OHL has participated in this program for approximately six years and has been within

specification 95.5 per cent of the time (n = 222). The majority of the non-proficient results occurred during the first year of participation in the program.

The other two external programs, Laval and Wisconsin, send samples bi-monthly and quarterly, respectively. The blood for these samples is obtained from collected pools of worker-exposed blood. The OHL's proficiency ratings in these two programs to date, are, Laval 95 per cent (n = 60) and Wisconsin 100 per cent (n = 21).

## Trends

As mentioned earlier, the Ontario regulation governing lead came into force in 1981. The questions of what effect the regulation has had and whether the lead levels of occupationally exposed workers in Ontario have dropped significantly from pre-regulation times are now being posed, some few years later.

To try to answer these questions, all the blood lead results produced by the Ontario Occupational Health Laboratory during the last six years, numbering some 68,000, have been scrutinized, categorized and analysed.

The blood lead results generated by the survey were categorized into the following five levels:

| | |
|---|---|
| ≤ 1.4 μmol Pb/L | (≤ 29 μg Pb/dL) |
| 1.5–1.9 μmol Pb/L | (30–39 μg Pb/dL) |
| 2.0–2.4 μmol Pb/L | (40–49 μg Pb/dL) |
| 2.5–3.3 μmol Pb/L | (50–69 μg Pb/dL) |
| ≥ 3.4 μmol Pb/L | (≥ 70 μg Pb/L) |

The companies from which the blood lead specimens were obtained were divided into two types, core and non-core (see Table 1). A core company was defined as one that had submitted at least one sample for each of the five years from 1980 to 1984. A non-core company merely had to have submitted one sample for any of the five years. This division into company types was necessary to determine if trends displayed by all the companies reflected a true change in blood lead levels or merely a change produced by a variable population of companies.

The survey results shown in Tables 2, 3 and 4 indicate quite clearly that blood lead levels in Ontario's occupationally exposed population have dropped dramatically over the last six years, particularly since 1981.

The proportion of results in the lowest category, less than or equal to 1.4 μmol Pb/L, has doubled from 30 per cent to 60 per cent. In the higher levels, 2.5 to 3.3

**Table 1** **Summary of Company Types**

| Year | Number of Companies | Number of Core Companies | Number of Non-Core Companies |
|---|---|---|---|
| 1979 | 61 | 31 | 30 |
| 1980 | 69 | 31 | 38 |
| 1981 | 86 | 31 | 55 |
| 1982 | 48 | 31 | 117 |
| 1983 | 156 | 31 | 125 |
| 1984 | 171 | 31 | 140 |

**Table 2** **Breakdown of Blood Lead Results for all Companies**

| | All Companies | | | | | |
|---|---|---|---|---|---|---|
| Year \ Range | ⩽ 1.4 umol/L | 1.5-1.9 umol/L | 2.0-2.4 umol/L | 2.5-3.3 umol/L | ⩾ 3.4 umol/L | Total No. of Samples/Year |
| 1979 | 31.2% | 13.6% | 15.4% | 32.7% | 7.1% | 9,279 |
| 1980 | 36.8% | 13.9% | 14.5% | 29.7% | 5.1% | 10,144 |
| 1981 | 43.7% | 15.1% | 14.5% | 22.8% | 3.9% | 9,312 |
| 1982 | 45.9% | 15.9% | 16.1% | 20.1% | 2.0% | 12,868 |
| 1983 | 55.4% | 15.2% | 13.5% | 14.5% | 1.4% | 12,372 |
| 1984 | 60.9% | 15.3% | 12.4% | 10.6% | 0.8% | 13,602 |

**Table 3** **Breakdown of Blood Lead Results for Core Companies**

| | Core Companies | | | | | |
|---|---|---|---|---|---|---|
| Year \ Range | ⩽ 1.4 μmol/L | 1.5-1.9 μmol/L | 2.0-2.4 μmol/L | 2.5-3.3 μmol/L | ⩾ 3.4 μmol/L | Total No. of Samples/Year |
| 1979 | 26.8% | 14.3% | 16.4% | 35.7% | 6.8% | 8261 |
| 1980 | 30.8% | 14.2% | 16.9% | 32.6% | 5.5% | 8925 |
| 1981 | 40.3% | 16.0% | 15.3% | 24.4% | 4.0% | 8298 |
| 1982 | 40.3% | 16.4% | 17.1% | 23.8% | 2.4% | 9096 |
| 1983 | 48.8% | 17.1% | 15.7% | 16.7% | 1.7% | 8558 |
| 1984 | 53.7% | 17.3% | 15.0% | 13.1% | 0.9% | 9906 |

μmol Pb/L and ⩾ 3.4 μmol Pb/L, the proportion has dropped to 30 per cent and 10 per cent of 1980 values respectively. The decrease in blood lead levels of all the companies, and of just the core companies, are similar to each other and, to a lesser extent, to those of the non-core companies. It is, however, reasonable to expect the

**Table 4**

**Breakdown of Blood Lead Results for Non-Core Companies**

| Year \ Range | Non-Core Companies | | | | | |
|---|---|---|---|---|---|---|
| | ≤ 1.4 μmol/L | 1.5-1.9 μmol/L | 2.0-2.4 μmol/L | 2.5-3.3 μmol/L | ≥ 3.4 μmol/L | Total No. of Samples/Year |
| 1979 | 66.7% | 8.2% | 7.1% | 8.6% | 9.4% | 1,018 |
| 1980 | 79.5% | 11.6% | 0.1% | 6.7% | 2.1% | 1,219 |
| 1981 | 72.0% | 7.5% | 7.9% | 9.6% | 3.0% | 1,014 |
| 1982 | 59.3% | 14.6% | 13.7% | 11.3% | 1.1% | 3,772 |
| 1983 | 70.2% | 11.0% | 8.5% | 9.6% | 0.7% | 3,814 |
| 1984 | 80.2% | 10.1% | 5.3% | 3.8% | 0.6% | 3,701 |

non-core trend to vary more than that of the others as its make-up is considerably more variable than that of all the companies of which it makes up some 10 to 30 per cent, depending upon the year in question.

The current result of lead control programs in Ontario is that in 1984 76 per cent of all blood lead levels were at or below 1.9 μmol Pb/L (39 μg Pb/dL), and only 0.8 per cent were at or above the alert level of 3.4 μmol Pb/L (70 μg Pb/dL). These figures compare very favourably with their 1979 counterparts of 44.8 per cent and 7.1 per cent, respectively.

It now remains to be seen if these encouraging trends will continue in the future until a point is reached where virtually all blood leads from Ontario's exposed populations stabilize at or below 1.9 μmol Pb/L. To monitor these trends and also to increase laboratory efficiency, the OHL has recently computerized its operations pertaining to biological samples. This new program, known as MESU, requires that all biological results produced by the OHL be processed and stored on computer. This information pool can then be accessed and manipulated by a number of different review screens. One of the most important of these is Techview, which, among other things, is able to review a worker's results profile, both current and historical, within a matter of minutes. Previously, this type of search would have required a considerable amount of time as the files would have had to have been culled manually. MESU will also enable the branch to determine trends similar to the one discussed above in a less time-consuming manner and to eventually produce studies based on individual worker trends as well as those of companies.

**Résumé**

Les trois techniques principales d'analyse du sang pour déceler le plomb, y compris la technique choisie par le Laboratoire des maladies professionnelles, et les programmes visant à évaluer la précision des analyses de dépistage du plomb dans le sang y sont décrits. Au terme de l'étude portant sur les analyses exécutées au cours des six dernières années par le Laboratoire des maladies professionnelles, on a pu constater qu'en général le taux de plomb sanguin des empolyés est en train de diminuer.

**R.E.M. Lees, M.D., F.F.C.M., F.R.C.P.(C), A.F.O.M.**

# Vanadium

## Summary

*Literature on environmental and occupational exposures to vanadium and its compounds is reviewed. Human health effects of exposure have been described periodically, if infrequently, in the past. Greatest health concern should centre on the pulmonary effects of long-term or repeated exposure, and special attention should be paid to workers handling soot or fly ash from oil combustion. Some guidelines for worker protection are presented.*

## Distribution

Although vanadium is widely distributed throughout the earth, it is not found in nature in elemental form. Vanadium compounds, oxides and vanadates are mined in Peru, Colorado and Western Australia. Because vanadium compounds are universally distributed in the earth's crust it is found in small quantities in most foodstuffs, and the usual human intake by mouth amounts to tens of micrograms per day.

Most foodstuffs contain less than one nanogram of vanadium per gram, but considerably higher concentrations are found in shellfish. The latter are the origin of vanadium in oil. The concentration in oil varies with the geographic source; Venezuelan and Arabian crude have high concentrations (350 ppm and 200 ppm respectively), but Western Canadian crude contains only a few parts per million. Vanadium is also found in coal – U.S. coal has 7 to 10 ppm.

So widely is vanadium distributed in nature that Schwartz and Milne[1] speculated that it was a trace element essential for mammalian growth. The total human body pool of vanadium has been estimated at 100 micrograms by Byrne and Kosta.[2]

## Metabolism

The $LD_{50}$ in rabbits by intravenous injection ranges from 9.18 to 14.66 mg per kg of body mass. The reported premortal effects by the parenteral route include drowsiness, convulsions, paralysis, bradycardia and a fall in blood pressure.

No accumulation of vanadium in any organ has been found and therefore it was considered by Byrne and Kosta that reliable measurements of intake should be possible from the measurement of output. Vanadium that has been ingested is excreted mainly in the stool with a small amount passing into the urine. The amount excreted in the faeces greatly exceeds that in the urine because vanadium is poorly absorbed from the gut. If, on the other hand, vanadium gets into the body through the respiratory tract, it is almost entirely excreted in the urine. There is some doubt about the normal urinary

*R.E.M. Lees, M.D., F.F.C.M., F.R.C.P.(C), A.F.O.M.*
*Occupational Health Resource Centre,*
*Queen's University,*
*Kingston, Ontario*

content of vanadium in the general population, but Byrne and Kosta were unable to detect vanadium in the range of 0.2 to 0.3 μg per litre in 24-hour samples.

In 1963 Soremark[3] reported that he could not detect vanadium in tooth enamel and this was confirmed by Nixon *et al*[4] who could not detect vanadium above a threshold of 10 nanograms per gram. However, using a different analytical technique, Losee *et al*[5] found mean concentrations of 17 nanograms per gram in tooth enamel, while Curzon *et al*[6] found a mean concentration of 36 nanograms per gram in 140 specimens of tooth enamel obtained in the United States of America.

Byrne and Kosta[2] found concentrations of 40 nanograms per gram in hair, and Soremark[3] reported finding a mean concentration of 29 nanograms per gram in 11 subjects in Stockholm. City air might contain as much as 1 μg per cubic metre at certain times. Undoubtedly, the mean concentration is considerably less. Most of this concentration of vanadium in city air comes from the burning of fossil fuels, but some probably originates in ground dust.

Basing their calculations on respired air volume of 20 cubic metres per day, Byrne and Kosta estimate that 1 μg of vanadium might be inhaled daily if the air concentration was 50 nanograms per cubic metre. Assuming this to be the case, probably little of that 1 μg would be absorbed into the body for a variety of reasons related to the absorption of materials from respired air. These same authors report finding concentrations of vanadium in tobacco of between 1 and 8 ppm.

## Uses

Vanadium is used in a wide variety of production processes as a catalyst, a mordant or an alloying material.

Ferrovanadium is used to produce special alloys of steel. The increase in tensile strength imparted to the steel makes it valuable for the manufacture of such things as automobiles and tools. Vanadium is also used to produce titanium alloy for jet engines and aircraft frame construction and can be alloyed with aluminum. Although its applications are principally metallurgical, vanadium compounds are employed as catalysts in the production of sulphuric acid and other chemicals in the manufacture of dyes and paints and as a mordant for dye fixing.

## Workplace Exposure

In mining and manufacturing industries the toxic hazard of vanadium usually results from the entry of the element as fume or of its compounds as dust through the respiratory tract. Absorption via the skin and intestinal

tract are not important routes of entry to the body.

Less obvious, but probably more frequent, sources of occupational exposure are soot and fly ash from oil combustion. Maintenance, repair and cleaning work in oil-fired furnaces and their heat exchange tubes exposes workers to very high doses of vanadium compounds. Combustion of oil in heating units concentrates the vanadium in the soot and fly ash so that these can contain up to 50 per cent vanadium or 80 per cent vanadium pentoxide.[7]

Fly ash and clinker from oil-fired furnaces are commercially attractive sources of vanadium containing much higher concentrations of the element than mined ores. Care is taken in cleaning units to collect all of the ash.

Maintenance workers cutting through heat exchange tubes with flame cutters are exposed to fume as well as to soot dust.

## Health Effects – A Review of the Literature

The first occupational exposure to vanadium was described by Dutton in 1911.[8] He reported on the effects of vanadium oxide on men who were exposed to it in industry, both as dust and fume. The men complained of dry, irritated coughs and bloody sputum and were found to have anaemia, albuminuria, haematuria, tremors, eye irritation, vertigo, hysteria and depression. In 1956, Gul'ko[9] described effects of vanadium compounds on workers exposed to dust ranging from 3.6 to 25.1 mg per cubic metre of air. Ninety-five per cent of the dust particles were reported to be less than 5 microns in size, and the dust consisted of a mixture of vanadium pentoxide, sodium metavanadate and ammonia metavanadate. Concentrations of vanadium in the urine of four men, varying from 0.02 to 0.05 mg per 100 mL were found; none was detectable in the urine of four controls. The study subjects were exposed for two to three months at a time. They complained of symptoms of irritation of the respiratory tract and eyes, sneezing, coughing, and scratchiness of the eyes, together with minor nosebleeds.

In 1962 Zenz *et al*[10] studied the effects on 18 workers of pure vanadium pentoxide in concentrations greater than 0.5 mg per cubic metre of air. The air sampling methods described in this study were inadequate, but the concentration was believed to be over 0.5 mg per cubic metre, with a mean particle size of less than 5 microns. Vanadium fume might also have been present from a high temperature kiln that was operating in the same plant.

Complaints, as were previously described, were dry cough, sore throat and burning eyes. On examination, Zenz reported the men to be suffering from conjunctivitis and inflamed throats, and they had numerous rales in the lungs. After two weeks the conjunctiva, the inflammation of the nose and throat, the cough, rales and wheezings had settled. Spirometry undertaken on these men two and four weeks after exposure was reported as being normal. Spirometry had not been conducted while the respiratory symptoms were present. The lung function measurements included FVC and $FEV_1$. Vanadium was apparently found in the urine for up to two weeks after exposure. Nine of the 18 workers were reported as having leukocytosis. The author noted that with subsequent exposures the symptoms increased in severity and had a more rapid onset, even though the dust concentrations were considered to be lower.

In 1955 Sjoberg[11] had reported examining seven men who cleaned oil burners. He described no air sampling techniques or the results of air sampling. Facemasks of an unspecified type were worn by all the men, three of whom subsequently complained of irritation of the eyes, six of irritation of the bronchi, five of wheezing, six of cough, three of fatigue and one of dyspnea. One man from this group was found to have bilateral bronchopneumonia on chest X-ray. The signs and symptoms of respiratory irritation appeared one to two days after the work had started and disappeared within a few days of the men leaving the contaminated area.

In 1967 Zenz and Berg[12] exposed volunteers to a concentration of 0.25 mg per cubic litre of vanadium pentoxide for eight hours. Within 24 hours of exposure all complained of cough, which disappeared in seven to 10 days. They observed no lung function test changes. The greatest reported vanadium concentration in the urine of these subjects was 0.013 mg per 100 mL, which was found about three days after exposure.

As early as 1946, Wyers[13] had described bronchopneumonia and pneumonitis in workers following exposure to vanadium. An irritant dermatitis has also been described affecting the majority of workers exposed to vanadium-containing dusts, but, at the same time, only a few exhibited sensitivity to material on patch testing with two per cent sodium vanadate.[14] No renal complications have been described following exposure to vanadium. Tebrock and Machle 1968[15] stated after an eight-year study of 250 workers that they could identify no permanent damage or systemic effects from continued

vanadium exposure. They concluded that the effects of exposure to vanadium phosphor, the substance found in the occupational environment in the study, were mainly of an acute nature and reversible on cessation of exposure. There are no comparable data available for vanadium pentoxide.

Lewis had drawn the same conclusion in 1959[16] after a study of men whose exposures had taken place over a six-month period. He did, however, warn of possible long-term effects and complications from the respiratory effects of vanadium exposure. This concern is also raised in a NIOSH report of 1977, which concludes, 'cases of bronchial asthma and bronchitis have been observed with sufficient frequency to warrant concern for decreased ventilatory function and possibly a progressively decreased ventilatory function on continuous exposure.'[17]

In 1980 Lees[18] reported on a study of respiratory function changes in 17 workers exposed to respirable dust (<10 micron particle size) containing 15.3 per cent vanadium. Significant ($p < 0.05$) reductions were noted in FVC and $FEV_1$ within 24 hours of exposure. The reductions in lung function persisted for more than eight days, but all the men had recovered their pre-exposure levels of lung function when tested four weeks after exposure. Symptoms of upper respiratory irritation were common, and 77 per cent of the men developed productive cough. Coarse rhonchi were audible on chest auscultation in 53 per cent of the men while 11 per cent had audible rales. Symptoms of respiratory irritation were not, by themselves, good indicators of reaction to exposure because two men without post-exposure complaints demonstrated clinically significant reductions in lung function. He concluded from the duration and character of the signs and symptoms that the respiratory reactions were not solely due to reflex bronchial reaction to irritation by non-toxic dust.

Most textbooks claim that green discoloration of the tongue is a sign of vanadium toxicity. Sjoberg made specific mention of the fact that he did not encounter green tongue in the 20 cases he studied. Lees[18] noted that the placement of soot containing vanadium pentoxide on the tongue results in green discoloration. That green discoloration is the result of the addition of moisture to vanadium pentoxide probably explains the report in the *Daily News* (Western Australia)[19] that workers in a 'vanadium plant in Wundowie suffer a reaction to vanadium which turns their tongues and testicles green.' The ore being refined contains vanadium pentoxide and

ammonium vanadate. Green discoloration of moist parts of the body is more likely evidence of exposure than toxicity.

There have been no reports of systemic carcinogenic, mutagenic, teratogenic or reproductive effects consequent on occupational exposures to vanadium.

## Current Regulations

The TLV (ACGIH 1984) of vanadium (as vanadium pentoxide) as respirable dust or fume in the working environment is 0.05 mg per cubic metre of air. While NIOSH[17] has specific regulations concerning the concentration of vanadium in the working environment, respirator use, environmental monitoring, worker education, sanitation and record keeping, Ontario has no specific regulations governing the use of vanadium in the workplace.

## Control, Monitoring and Preventive Measures

Further study of the health effects of vanadium is required. Acute exposures to vanadium and its compounds can cause eye and upper respiratory irritation, bronchitis, pneumonitis and reversible changes in lung function, but the long-term effects of chronic or repeated exposure are unknown.

Specific regulations are unnecessary for the application of common sense in the handling of vanadium compounds and metallic fume. Mining and ore milling are not carried out in Ontario, or in Canada, and good hygiene practice should be able to keep airborne concentrations below the ACGIH-TLV in metallurgical applications. Boiler repair and maintenance present the greatest threat of exposure to workers, but careful attention to precautions should eliminate adverse health effects on those who have to work in such situations.

Persons with chronic respiratory disease should be precluded from work where vanadium exposure is likely. It has also been suggested that skin patch testing with a two per cent sodium vanadate solution should be undertaken to exclude those with skin sensitivity.[20]

Prior to entry into oil-fired furnaces, water lancing can reduce the amount of soot adhering to boiler tubes. Despite lancing, the airborne concentration of soot and ash will reach high levels when cleaning is undertaken, and the fume hazard will be present during tube cutting and replacement. Self-contained air packs with full facemasks should be provided for short-term entry or on-line air supplied respirators when longer periods must be spent in the unit.

Some people seem to be relatively resistant to the

effects of vanadium exposure and will not exhibit symptoms when others will. The value of biological monitoring may be questioned, but severe pulmonary complications can develop in individuals who have failed to manifest any of the less severe and transient symptoms of exposure. Absorbed vanadium is rapidly excreted in the urine – 90 per cent clearance within 24-36 hours – so that timing of sample collection is important in biological monitoring. Analysis of urine for vanadium concentration is difficult, but because vanadium is almost undetectable in the urine of non-occupationally exposed persons, exact quantification is unnecessary to indicate absorption. A test threshold of 10 micrograms per litre (0.2 micromol/L) of urine should be adequate.

Disposable non-absorbent coveralls should be worn during furnace work and removed for destruction at the end of the shift.

Precautions against skin exposure should be taken because irritant and possibly allergic dermatitis can occur.

Persons regularly employed in situations of potential vanadium exposure should undergo periodic medical examination with particular attention paid to lung function tests.

**Résumé**

L'étude porte sur la documentation relative à l'exposition au vanadium et à ses composés dans l'environnement et en milieu de travail. Auparavant, les effets de l'exposition à ces produits sur la santé de l'être humain ont été décrits périodiquement bien qu'à de rares intervalles. Au niveau de la santé, on devrait surtout se préoccuper de l'effet des expositions prolongées ou répétées sur les fonctions respiratoires particulièrement chez les employés qui manipulent la suie ou les cendres volantes provenant de la combustion d'huile. On a présenté quelques directives sur des mesures de protection de l'employé.

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# Exposure to Ethylene Oxide in Hospitals in Ontario*


## Summary

*In response to the proposed designation of ethylene oxide, a task force was established to investigate its use in Ontario hospitals. Detailed air sampling was conducted in a selected number of hospitals in a pilot study to determine worker exposure. Hygiene surveys were included to assess appropriate control strategies for their effectiveness and to suggest improvements to further reduce exposures.*

*This paper reports the results of the air monitoring and hygiene surveys, which formed a part of the task force report.*


On November 13, 1982 a Notice of Intention to designate ethylene oxide was published in *The Ontario Gazette*.

Two of the 28 submissions received in response to the notice came from the health care related groups – the Ontario Hospital Association (OHA) and the Canadian Union of Public Employees (CUPE), which represents hospital workers.

Following discussions with the two groups, the ministry established a task force to survey a representative number of hospitals to investigate the current status of measures for controlling exposure to ethylene oxide in hospitals and to obtain information covering the nature and extent of the costs of implementing a regulation, with particular attention to the costs of reducing worker exposure in hospitals, the only establishments in the health care sector where ethylene oxide is used. This paper deals with the technical and exposure assessment segments of this survey. Both OHA and CUPE agreed to co-operate.

A list of hospitals to be visited was approved by CUPE and OHA. OHA contacted each chief executive officer of the 21 hospitals to explain the purpose of the study and to request permission to visit. All expressed their willingness to participate. Air sampling and analysis for ethylene oxide were to be performed by staff from the Occupational Health Branch (OHB) of the Ministry of Labour.

## Ethylene Oxide and the Sterilization Process

### Introduction

Occupational exposure to ethylene oxide gas or liquid has resulted in a variety of acute toxic effects including respiratory tract and skin irritation, chemical burns, skin sensitization, vomiting and diarrhea. Chronic effects may include respiratory irritation, secondary respiratory infection and anaemia.

Ethylene oxide has been reported to be carcinogenic in

*This paper is an abridged version of the task force report on the Survey of Ethylene Oxide Use in Ontario Hospitals, which is available in the Ministry of Labour Library, 400 University Avenue, Toronto, Ontario M7A 1T7, and in the Ministry's regional offices.

animals, and the National Institute of Occupational Safety and Health in the U.S.A. (NIOSH) and some other agencies have recommended that it be treated as if it were a human carcinogen. In April 1984 the U.S. Occupational Safety and Health Administration (OSHA) promulgated a new regulation for ethylene oxide because of its reported carcinogenicity. Reproductive toxic effects of ethylene oxide on animals have been reported, and one study has provided some data suggesting an increased risk of spontaneous abortions in women exposed to ethylene oxide.

Liquid ethylene oxide distributed in glass ampoules (1.5 to 3 g) or small metal cartridges (30 to 134 g), usually called the unit-dose form, is intended for one-time use. These containers are used by hospitals that use cabinet sterilizers with capacities of four cubic feet (about 0.11 cubic metres) or less. Mixtures of ethylene oxide and inert gases in cylinders or tanks are usually used with sterilizers that have capacities of more than four cubic feet. The most common form used in the hospitals surveyed was the 12/88 mixture (12 per cent ethylene oxide by weight in 88 per cent Freon-12 (dichlorodifluoromethane)). Ethylene oxide is also available in a 10/90 w/w mixture with carbon dioxide, but none was found in this survey. Ethylene oxide is diluted by these inert gases to the 10 to 12 per cent range to render the mixtures non-flammable.

Ontario hospitals began using ethylene oxide sterilizers in the late 1960s. Their main advantage is their ability to sterilize materials that are sensitive to the extreme heat and/or moisture conditions used in steam sterilizations.

Normally, sterilization with ethylene oxide is carried out in a closed chamber at temperatures ranging from 37°C to 60°C for two to twelve hours depending on the charge of ethylene oxide and the temperature of sterilization. Currently, most sterilization procedures in Ontario are carried out at pressures greater than atmospheric pressure. Following the sterilization process, materials are aerated to remove residual amounts of ethylene oxide.

## Types of Sterilizers

In general, three types of sterilizers are used. Sterilization by the tray method is carried out in a small table-top cabinet, using undiluted ethylene oxide in a unit-dose glass ampoule. The glass ampoule is opened manually inside a gas-permeable plastic bag containing the materials to be sterilized. This is quickly placed inside

the cabinet, after which the cabinet door is closed until the sterilization process is complete.

Another type of table-top, or cabinet, sterilizer uses undiluted ethylene oxide gas in unit-dose cannisters, or cartridges. These cartridges have a plastic tip that can be punctured after the cartridge is inserted in the sterilizer. However, care must be taken to ensure that the cartridges are punctured at the appropriate time during the sterilization process, as specified by the manufacturer.

The third type of sterilizer uses ethylene oxide diluted with fluorohydrocarbons (or carbon dioxide), which is supplied from floor-standing cylinders usually kept in the sterilizer area or in the mechanical room adjacent to the sterilizer area.

At the end of the sterilization cycle, the used ethylene oxide gas is removed by a vacuum pump and mixed with water for disposal down the sanitary sewer drain. After the sterilizer chamber has been maintained under vacuum for the prescribed length of time, the pressure is returned to atmospheric with filtered air. Nevertheless, residual ethylene oxide will be absorbed by the sterilized materials and must be removed by aeration.

The most common practice is to open the sterilizer door slightly and to have personnel leave the area for 15 minutes before the load is transferred to the aerator. This allows for capture of ethylene oxide by local ventilation hoods at the door. The load is then transferred to an aerator to remove the residual ethylene oxide in the sterilized materials.

## Aerators

Removal of residual ethylene oxide may also be accomplished in mechanical aerators, which are cabinets capable of heating, filtering and circulating air. The mechanical aerator is much faster, more efficient, more reliable and safer in reducing residual ethylene oxide levels in sterilized materials than the old method of aeration in room air. Mechanical aerators can be provided with forced-air ventilation, which allows residual ethylene oxide to be removed more quickly and exhausted directly to the outside atmosphere. Typical aeration times are 12 hours at an aerator chamber temperature of 50°C and eight hours at a temperature of 60°C. At room temperature, it would take about one week to accomplish the same degree of aeration.

## Potential Sources of Occupational Exposure to Ethylene Oxide

Exposure to ethylene oxide is most likely to occur when the sterilizer door is opened at the end of the sterilization cycle. Although ethylene oxide vapour is heavier than air, the elevated temperature and humidity used in the sterilization process cause the ethylene oxide to rise and then disperse throughout the sterilizer area when the sterilizer door is opened. Residual ethylene oxide levels in the sterilized materials, which are highest at the end of the sterilization cycle, are given off most rapidly when the materials are first removed from the sterilizer. These materials will continue to contribute to the ambient ethylene oxide levels in the sterilizer area until they are placed in an aerator. The duration of ethylene oxide release from sterilized materials at room temperature can be appreciable depending on the size and nature of the load.

In most of the hospitals surveyed, the ethylene oxide from the vacuum pump of the sterilizer is mixed with water, which then empties into an open drain in the adjacent mechanical room in the sterilizer facility or, in a few cases, in the sterilizer area. The effluent water may be passed through a gas-water separator at the drain site to remove some of the ethylene oxide from it before it enters the sanitary sewer system. In any event, without suitable local ventilation of the drain area, release of ethylene oxide may contribute significantly to the ambient levels in the air. If the drain is in the mechanical room, and if the room is not well ventilated or under negative pressure with respect to the adjacent sterilizer area, then the ethylene oxide may diffuse from the mechanical room to the sterilizer area.

Exposure to ethylene oxide liquid and/or gas remaining in connecting hoses or tubing may occur during cylinder changing. Occupational exposures may also occur from leaky sterilizer door gaskets and aerators and during maintenance and repair work, especially for equipment malfunction or breakdown.

## Survey Measurements of Airborne Ethylene Oxide and Occupational Exposure

As part of the hospital survey, ministry staff carried out area and personal sampling in each of the sterilizing facilities visited.

The 21 hospitals that participated in the study represent about 15 per cent of the estimated 140 hospitals in Ontario that use ethylene oxide. Three of these had two separate areas where materials were sterilized with

ethylene oxide. The hospitals were selected jointly by CUPE and OHA, and are considered representative with respect to size and geographic location.

The number of sterilizer operators and other workers who may be exposed to ethylene oxide varies widely with the size of hospital. The numbers ranged from a total of six operators handling three to four loads a week to 63 workers in one hospital handling 45 loads a week. The average number of operators in the hospitals surveyed was about 15 and ranged between four and 50. The average number of potentially exposed workers was 23 and ranged between six and 65.

The pattern of staff rotation among sterilizer operators also differed greatly from hospital to hospital; for example: one to two days a week; five days a week every four to 10 weeks; and five days a week for three consecutive weeks with a rotation every 19 weeks.

## Sampling and Analysis

A personal sampling pump was used to draw air through two jumbo charcoal tubes in tandem at a rate of 0.05 L/min for no longer than 100 minutes. Sample tubes were refrigerated to prevent the loss or decomposition of samples until they were analysed.

The ethylene oxide in the sample tubes was first desorbed from the charcoal with a benzene solution containing one per cent carbon disulphide and then subsequently converted to 2-bromoethanol by treatment with hydrobromic acid. The bromine-containing derivative was analysed by a gas chromatograph equipped with an electron capture detector (ECD).

The lower limit of detection is 0.001 mg, which corresponds to a time-weighted average concentration of about 0.1 ppm based on the maximum air sampling volume of 5 L. The lower detection limit for short-term sampling for a maximum concentration determination corresponds to approximately 0.7 ppm for a 0.75 L air sample collected over 15 minutes at the same sampling rate.

## Survey Sampling Protocol

Both area and personal sampling were conducted at each of the participating hospitals. In hospitals with more than one sterilizer, each sterilizing facility and operator was monitored.

Area samplers were placed over the sterilizer door, in the work area near the sterilizer, at the aerator and work bench and in other areas where applicable. These other

areas included the storage area containing freshly sterilized materials, the storage area for the ethylene oxide tanks or cartridges and the area over the drain where ethylene oxide-containing water is discharged. In most hospitals the water outlet and drain are in the mechanical room. In two hospitals this drain was in the sterilizer area. During the visits it was observed that some areas were air-conditioned by a unit also serving the sterilizer area, even though they were not part of the sterilizer facility. These areas, which might have residual ethylene oxide, were also sampled.

Personal samplers were placed on the sterilizer operators since they are the most likely of all the staff to come in contact with ethylene oxide under normal sterilizing conditions. In some cases other workers in the sterilizer area were also monitored, especially if more than one person per shift loaded and unloaded the sterilizer. The operators were monitored during phases of sterilization/aeration, when they were most likely to be exposed to ethylene oxide. Maximum personal exposures were determined by sampling for 15-minute periods when the sterilizer door was slightly ajar at the end of a sterilization cycle and when the door was fully opened prior to transferring sterilized goods to the aerator. Depending on the sterilizing cycle, each operator was monitored continuously for $2^1/_2$ to six hours.

During the survey of the 21 hospitals, 29 personnel and 92 locations were monitored in the 24 sterilizer facilities present. Up to five sets of sampling tubes were used sequentially for continuous monitoring of each person or area for the duration of the sampling period.

Sampling times for personal and area sampling were synchronized with the various phases of the sterilization process including:

- loading the sterilizer;
- charging the chamber with ethylene oxide;
- the sterilization phase;
- purging the chamber;
- opening the sterilizer chamber door;
- unloading and transferring goods from the sterilizer to the aerator; and
- aeration.

## Sampling Results

In this report airborne concentrations are derived from area sampling and time-weighted averages *for the duration of sampling only*. *In the discussion*, personal

exposures are 40-hour time-weighted average exposures calculated from the values determined over the total sampling time ($2^1/_2$ to six hours). These calculations took into account the worker's schedule and the number of sterilizer loads handled per week. Times of exposure for individual operators per week ranged from $7^1/_2$ to $37^1/_2$ hours.

Results of the air sampling are listed in Tables 1a, 1b and 1c on the basis of sterilizing facilities (individual sterilizing areas).

From the data it appears that the personal exposures may be classified into three distinct groups:

i) exposures that are not detectable, i.e. under 0.1 ppm;
ii) exposures ranging from 0.1 to 0.3 ppm; and
iii) exposures ranging from 0.7 to 0.9 ppm.

Some 480 workers, including maintenance staff, are potentially exposed to ethylene oxide in these 21 hospitals. One of the 29 personal samples taken was spoiled, so the following discussion is based on only 28. (After the task force completed its visits, the Occupational Health Branch conducted further air sampling at the hospital where the personal sample was spoiled. The results from this repeat sampling (non-detectable to 0.3 ppm) confirmed that the personal exposures at this hospital were less than 1 ppm on a 40-hour time-weighted average. The sampling results from this visit are not included in the discussion of the survey results.)

The number of workers in each of the three exposure categories is shown below. In one of the sterilizing facilities, two personal samples were collected that showed different exposures, one 0.1 ppm and the other non-detectable. However, this difference is not statistically significant since the detection limit is 0.1 ppm.

| Group | Range of Personal Exposures (ppm, 40-hour TWA) | No. of Workers Monitored | No. of Sterilizing Facilities |
|---|---|---|---|
| 1 | Non detectable | 17 | 14 |
| 2 | 0.1 – 0.3 | 8 | 8 |
| 3 | 0.7 – 0.9 | 3 | 3 |

## TABLE 1a — Group 1 With No Detectable Personal Exposure (TWAE) to Ethylene Oxide

| Sterilizing Facility | Personal Exposure | | Sterilizer Area | | Aerator Area | | Work Area | | Mechanical Room | | Other | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TWAE[1] | Max | TWA[2] | Max | TWA | Max | TWA | Max | TWA | Max | Area | TWA | Max |
| 1 | ND[3] | | ND | | ND | | ND | | ND | | | | |
| 2 | ND | | ND | | N/O[5] | | ND | | ND | | | | |
| 3 | ND | | ND | | ND | | ND | | 0.9 | 1 | | | |
| 4 | ND | | ND | | ND | | ND | | 1.1 | 15 | | | |
| 5 | ND | | ND | | ND | | ND | | 1.7 | 14 | | | |
| 6 | ND | | ND | | N/O | | ND | | 11 | 21 | | | |
| 7 | ND × 2[4] | | ND | | N/O | | — | | 2.4 | 5 | | | |
| 8 | ND × 2 | | ND | | 0.3 | | — | | 1.5 | 21 | | | |
| 9 | ND | | ND | | 0.9 | 2 | — | | <1.7[6] | 12 | | | |
| 10 | ND | | 0.1 | | 0.5 | 7 | 0.1 | | ND | | | | |
| 11 | ND × 2 | | 0.3 | | 0.9 | | ND | | 5.4 | | Cylinder Area | ND | |
| 12 | ND | | 0.3 | 4 | ND | | ND | | 2.8 | 15 | | | |
| 13 | ND | | 0.6 | 15 | ND | 2 | — | | 5.4 | 25 | | | |
| 14 | ND | | 1.7 | 5.9 | N/O | | ND | | 2.2 | 11 | | | |
| Sub-total – personnel/ areas sampled | 17 | | 14 | 3 | 10 | 3 | 10 | | 14 | 10 | | 1 | |

1. TWAE – 40-hour time-weighted average exposure.
2. TWA – Time-weighted average concentration for duration of measurement period.
3. ND – Not detectable below detection limit of 0.001 mg. This corresponds to about 0.1 ppm TWAE for long-term sampling or 0.7 ppm for a maximum concentration measured over 15 minutes.
4. ND × 2 – Indicates that two personal samples were collected in this area.
5. N/O – Indicates that equipment was not in operation during visit.
6. < – Indicates that concentration of ethylene oxide was not detectable during most of the sampling period. The TWAE/TWA was calculated by assuming that the concentration was 0.1 ppm for these periods.

## TABLE 1b — Group 2 with Personal Exposures Ranging from 0.1 to 0.3 ppm

| Sterilizing Facility | Personal Exposure | | Sterilizer Area | | Aerator Area | | Work Area | | Mechanical Room | | Other | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TWAE[1] | Max | TWA[2] | Max | TWA | Max | TWA | Max | TWA | Max | Area | TWA | Max |
| 15 | 0.1 | | ND[3] | | ND | | 0.2 | | ND | | | | |
| 16 | 0.1 | | ND | | N/O[4] | | ND | | 2 | | | | |
| 17 | 0.1 | 0.1 | 0.1 | | 0.5 | 7 | 0.1 | | ND | | | | |
| 18 | 0.1 | | 0.5 | | 0.3 | 0.5 | 0.3 | 0.5 | 0.1 | | | | |
| 19 | <0.2[5] | 0.7 | <0.1 | | 0.3 | | 0.3 | | 2.0 | 7.6 | | | |
| 20 | 0.2 | | 0.2 | | 0.3 | | 0.2 | | 0.2 | | Room adjacent CSR[6] | 0.4 | |
| 21 | 0.3 | 3.2 | 0.1 | | <1.3 | 3.5 | ND | | | | Drain Storage | <1.3 | 3.5 |
| 22 | <0.3 | 3.7 | 0.2 | | near sterilizer | | 1 | 7 | 0.2 | 0.7 | | ND | |
| Sub-total – personnel/ areas sampled | 8 | 4 | 8 | | 6 | 3 | 8 | 2 | 7 | 2 | | 2 | 1 |

1. TWAE – 40-hour time-weighted average exposure.
2. TWA – Time-weighted average concentration for duration of measurement period.
3. ND – Not detectable below detection limit of 0.001 mg. This corresponds to about 0.1 ppm TWAE for long-term sampling or 0.7 ppm for a maximum concentration measured over 15 minutes.
4. N/O – Indicates that equipment was not in operation during visit.
5. < – Indicates that concentration of ethylene oxide was not detectable during most of the sampling period. The TWAE/TWA was calculated by assuming that the concentration was 0.1 ppm for these periods.
6. CSR – Central Supply Room.

**TABLE 1c — Group 3 with Personal Exposures Ranging from 0.7 to 0.9 ppm**

| Sterilizing Facility | Personal Exposure | | Sterilizer Area | | Aerator Area | | Work Area | | Mechanical Room | | Other | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TWAE[1] | Max | TWA[2] | Max | TWA | Max | TWA | Max | TWA | Max | Area | TWA | Max |
| 23 | 0.7 | 4 | 0.5 | 15 | 0.3 | | 0.3 | | — | | | | |
| 24 | 0.8 | 10.5 | 0.2 | | 1 | 7 | 0.2 | | — | | Drain | 0.2 | 0.7 |
| 25 | 0.9 | 2.1 | 3.4 | 9.8 | 0.9 | 9.8 | — | | 3.7 | 24 | Storage | 1.5 | 3 |
| Sub-total –personnel/ areas sampled | 3 | 3 | 3 | 2 | 3 | 2 | 2 | 0 | 1 | 1 | 1 | 2 | 2 |

1. TWAE – 40-hour time-weighted average exposure.
2. TWA – Time-weighted average concentration for duration of measurement period.

## Discussions of Survey Results

From the air sampling results it is concluded that all of the hospitals could meet a regulatory requirement to maintain ethylene oxide exposure to levels under 1 ppm on a 40-hour time-weighted average basis and under 10 ppm maximum concentration. None of the personal exposures exceeded a 40-hour time-weighted average of 1 ppm. The maximum concentration of 10 ppm was exceeded in only one personal sample.

In fact, no detectable ethylene oxide was measured in 17 of the 28 personal samples. Twenty-one personal samples out of 28 showed levels at or below 0.1 ppm (as a 40-hour time weighted average), and 25 personal samples were at or below 0.3 ppm.

During this survey it was observed that work practices contributed significantly to reducing personal exposures. For example, it was general practice for workers to leave areas where ethylene oxide is likely to escape or be exhausted, such as the area near the sterilizer, just after the door was opened at the end of a sterilization cycle. Also, mechanical rooms were not entered while the ethylene oxide was being exhausted from the sterilizer chamber. Staff rotation also results in decreasing the overall exposure of workers to ethylene oxide. One way to ensure that personal exposures are always below 1 ppm as a time-weighted average is to implement engineering controls that can maintain area levels of ethylene oxide below a time-weighted average level of 1 ppm and below a maximum concentration of 10 ppm.

A number of changes could be made in hospitals to ensure that ethylene oxide exposures are maintained below this level at all times by engineering controls rather than work practices and administrative controls. This would require, in part, ventilation of good design in the sterilizer and aerator areas and in the mechanical rooms.

The exhaust from the sterilizer facility should not be vented to general exhaust where it may be mixed with air and recycled throughout the hospital. Dedicated exhaust systems should be in place and the outside exhaust vent should be situated away from air intake vents.

It is also good general industrial hygiene practice to restrict access to the areas around the sterilizer and aerator. This can be accomplished only where the sterilizer and aerator are isolated from the general central supply room work area. Similarly, access to the mechanical room should be limited to maintenance personnel and any others who are responsible for changing ethylene oxide cylinders. In addition to decreasing the potential number of ethylene oxide-

exposed workers, isolation of the sterilizing facility decreases the work area space, which otherwise would require higher capacity ventilation, and lowers the cost of controlling its ethylene oxide levels.

### Air Sampling Results Around Drain Areas

These results are discussed separately because most drain areas are in mechanical rooms, which, normally, are not entered by hospital staff during the sterilization process. There appeared to be no correlations between airborne ethylene oxide concentrations in mechanical rooms and those in sterilizer and work areas or in the reported personal sampling results. However, this generalization applies only when the mechanical room is maintained under negative pressure with respect to the sterilizer area.

By contrast, the mechanical room in facility #25, which was not under negative pressure, had high ethylene oxide levels (a time-weighted average concentration of 3.7 ppm and a maximum concentration of 24 ppm) and the highest personal exposure in the survey (a 40-hour time-weighted average exposure 0.9 ppm). The greatest personal exposures within the entire sampling period occurred when the sterilizer was being purged. At this time the ethylene oxide levels were at their highest in the mechanical room, as was expected. However, they were also at their highest in the sterilizer area, apparently due to air flow from the mechanical room.

Fifteen of the 17 hospitals that use vacuum pumps to exhaust ethylene oxide from the sterilizers had water drains placed in mechanical rooms. The concentrations of ethylene oxide around these drain areas ranged widely from non-detectable to 27 ppm.

## Engineering Controls for a 1 PPM Time-Weighted Average Limit

### Sterilizer Areas

Only one hospital had a maximum area concentration that exceeded 10 ppm in the sterilizer area. In this case, the 'tray method' of sterilization was used. A concentration of 15 ppm was measured during the 15-minute period following the opening of the cabinet door. The ventilation system should be designed so as to prevent ethylene oxide exposure when the glass ampoule is snapped open before it is placed in the sterilizer. Any hospital using the tray method should take immediate action to lower the potential of exposure to ethylene oxide where appropriate ventilation is not currently in place.

The time-weighted average concentrations in the sterilizer areas in facilities #14 and #25 were above 1

ppm while the maximum concentrations were respectively 5.9 and 9.8 ppm. Suitably designed local exhaust hoods installed as close as possible to the door opening of each sterilizer would control these time-weighted average concentrations below 1 ppm. In addition, retro-fitted multiple vacuum purge systems would ensure lowered concentrations by lessening the amount of ethylene oxide remaining in the sterilizer chamber at the end of the sterilization cycle.

Furthermore, it is good industrial hygiene practice to limited access to the immediate sterilizer area to a few, authorized personnel. Excessive access (30 to 60 persons) to the sterilizer area was noted in four hospitals.

## Aerator Areas

The air sampling results indicated that only one aerator area monitored during the survey had a time-weighted average concentration above 1 ppm and none had maximum concentrations exceeding 10 ppm. Ventilation should be improved in the area of this one aerator.

Three large hospitals have insufficient aerator capacity to handle the routine number of sterilized loads. Sterilized materials that cannot be placed in the aerator are currently stored on open shelving.

Generally speaking, the highest results from personal sampling and aerator area air sampling were found in these hospitals. Because these storage areas are also high traffic areas (e.g. hallways), many workers can be exposed unnecessarily. Eventually, each of these facilities should purchase an additional mechanical aerator so that the total sterilizer capacity can be handled routinely. As an interim measure, storage areas for freshly sterilized materials should be isolated and well ventilated.

## Mechanical Rooms

The mechanical rooms generally contain the ethylene oxide tanks and the open drain where ethylene oxide-laden water is flushed. Air sampling in these areas was carried out at each of the hospitals during the operation of the sterilizers but only at one facility during the changing of tanks. In the latter case no ethylene oxide exposure could be detected. The average concentration exceeded 1 ppm in 13 of the 22 mechanical rooms surveyed. In addition, the maximum concentration of 10 ppm was also exceeded in nine of these mechanical rooms. Local ventilation around the open drain would be more efficient and cost-effective than general room ventilation. It should be noted that plumbing codes in many municipalities do

not permit a closed drain system. Local ventilation in the drain area and around the ethylene oxide cylinder(s) should be installed.

It was noted that in three hospitals the gas cylinders connected to the sterilizers were in the sterilizer area. If practical, these cylinders should be moved to the mechanical room or to an isolated, ventilated area where the temperature does not exceed 20°C to 25°C.

## Other Control Measures

An additional measure to ensure that other workers (and patients) are not exposed unnecessarily or accidentally to ethylene oxide is to exhaust all ethylene oxide directly to the outdoors. The exhaust should not go to the general ventilation system since equipment failures, malfunctions or leakages may result in the release of ethylene oxide to other areas in the hospital. Such systems venting directly to the outside atmosphere should not be exhausted near any air inlet. Improperly installed air conditioners can also cause ethylene oxide to accumulate in work areas where it is not used or should not be present. Dedicated exhaust systems for sterilizer areas were found in only three hospitals.

There should be an active preventive maintenance program that includes the regular inspection of equipment for any evidence of wear or leaks in the sterilizers and aerators. Ventilation flow rates should be checked to determine if they continue to meet specified requirements. The majority of staff supervisors at the hospitals surveyed indicated that they had regular maintenance programs; however, the air sampling results demonstrated that a number of sterilizers and aerators appeared to have leaky door gaskets, which resulted in the release of ethylene oxide in the work areas.

Good housekeeping practices will also assist in controlling ethylene oxide exposure. For example, louvered vents can become blocked with dust and debris, which would lead to a decrease in, or elimination of, air flow. This was not observed during the current survey, but has been observed in recent regular Occupational Health Branch visits.

A comprehensive training course augmented with periodic refresher courses for operators and maintenance staff will reinforce the need for preventive maintenance programs and good housekeeping practices, as well as other work practices. Three observations emphasize the need for the training of staff in sterilizer facilities. First, operators in most facilities wore surgical masks for

'protection' against the effects of ethylene oxide exposure. Surgical masks offer no such protection since they are completely permeable to ethylene oxide vapours and other gases. Second, high results were obtained in some personal samples collected while the operators were transferring sterilized goods from the sterilizer to the aerator. It appears that these operators were not waiting the recommended 15 minutes after the sterilizer door was opened before unloading the goods. In at least one other instance, freshly sterilized materials were left on a cart beside the sterilizer for 15 to 30 minutes before they were transferred to the aerator. These materials should be transferred to the aerator immediately after removal from the sterilizer.

**Acknowledgements**

The involvement of the Ontario Hospital Association, the Canadian Union of Public Employees and ministry staff was extensive, and appreciation is extended to those in each organization.

The Editorial Board of Occupational Health in Ontario wishes to thank Dr. M.A. Nazar for preparing this summary.

**Résumé**

Étant donné la désignation proposée de l'oxyde d'éthylène, un groupe de travail a été formé pour étudier son utilisation dans les hôpitaux de l'Ontario. On a donc établi un projet pilote consistant en l'échantillonnage soigneux de l'air dans certains hôpitaux sélectionnés afin de déterminer le degré d'exposition des employés à ce produit. On a procédé notamment à une étude des mesures d'hygiène pour évaluer l'efficacité des stratégies de contrôle appropriées et afin de pouvoir suggérer des moyens de réduire davantage les possibilités d'exposition.

Cet article donne les résultats d'analyses de l'air et d'études des mesures d'hygiène dont rend compte le rapport du groupe de travail.

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| October 14-17, 1985 | 2ND National Congress of Hygiene and Epidemiology, HAVANA, CUBA. For further information, contact National Council of Medical Scientific Societies, Calle 4 No. 407 entre 17 y 19, Vedado, Ciudad de La Habana, Cuba. |
| October 21-25, 1985 | Joint Conference on Occupational Health – American Academy of Occupational Medicine and American Academy of Industrial Hygiene. Sheraton World Hotel, ORLANDO, FLORIDA. |
| November 4-8, 1985 | 14th Annual Ontario Occupational Health Nurses Association Conference, L'Hotel, TORONTO, CANADA. For further information contact Mrs. B.J. Varey, Sun Life Assurance Co. of Canada, P.O. Box 4150, Station A, Toronto, Ontario, Canada, M5W 3C9. |
| November 18-21, 1985 | International Symposium on Ergonomics in Developing Countries, JAKARTA, INDONESIA. Further information may be obtained from International Labour Office, Occupational Safety and Health Branch, CH-1211 Geneva 22. |
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